

ARTICLE

Interactive Methods for Teaching Action Potentials, an Example of Teaching Innovation from Neuroscience Postdoctoral Fellows in the Fellowships in Research and Science Teaching (FIRST) Program

E. Keen-Rhinehart,^{1,5} A. Eisen,³ D. Eaton,² and K. McCormack^{1,4}

¹Division of Psychobiology, Yerkes National Primate Research Center, ²Dept. of Physiology, ³Dept. of Biology, Emory University, Atlanta, GA 30322; ⁴Dept. of Psychology, Spelman College, Atlanta, GA 30314; ⁵Department of Biology, Susquehanna University, Selingsgrove, PA 17870

Acquiring a faculty position in academia is extremely competitive and now typically requires more than just solid research skills and knowledge of one's field. Recruiting institutions currently desire new faculty that can teach effectively, but few postdoctoral positions provide any training in teaching methods. Fellowships in Research and Science Teaching (FIRST) is a successful postdoctoral training program funded by the National Institutes of Health (NIH) providing training in both research and teaching methodology. The FIRST program provides fellows with outstanding interdisciplinary biomedical research training in fields such as neuroscience. The postdoctoral research experience is integrated with a teaching program which includes a How to Teach course, instruction in classroom technology and course development and mentored teaching. During their mentored teaching experiences, fellows are encouraged to explore innovative teaching methodologies and to perform science teaching research

to improve classroom learning. FIRST fellows teaching neuroscience to undergraduates have observed that many of these students have difficulty with the topic of neuroscience. Therefore, we investigated the effects of interactive teaching methods for this topic. We tested two interactive teaching methodologies to determine if they would improve learning and retention of this information when compared with standard lectures. The interactive methods for teaching action potentials increased understanding and retention. Therefore, FIRST provides excellent teaching training, partly by enhancing the ability of fellows to integrate innovative teaching methods into their instruction. This training in turn provides fellows that matriculate from this program more of the characteristics that hiring institutions desire in their new faculty.

Key words: action potential, postdoctoral fellowship, interactive teaching, pedagogy, neuroscience, mentoring

According to the American Association of Colleges and Universities (AACU), knowledge of one's field is necessary but not sufficient to be successful as a new faculty member in academia. Hiring institutions would like new faculty to arrive ready to teach because teaching is the responsibility that will demand the majority of their time and effort initially upon their arrival (Adams, 2002). Competition for jobs in academia has become increasingly intense, and an increased emphasis has been placed on the potential quality of teaching that applicants can provide. It is no longer the case that providing well-structured lectures qualifies for excellence in teaching. To be competitive for these positions, candidates must demonstrate the ability to bring creativity, interaction, student engagement and an understanding of varied learning styles to their teaching methodologies (Adams, 2002). Some universities even offer higher base salaries for applicants with evidence of specialized classroom training (Benyajati, 2007; Adams, 2002). Unfortunately, the teaching experience of applicants for positions in academia can be highly variable, and most hiring committees do not think that candidates are adequately prepared for college teaching (Adams, 2002).

Until recently, few mechanisms provided support for postdoctoral career development in areas such as teaching and mentoring (Holtzclaw et al., 2005; Brommer and Eisen, 2006; Benyajati, 2007). Opportunities to develop teaching skills or even acquire teaching experience have often been

categorically discouraged by postdoctoral advisors. Most research mentors have the view that since teaching skills are not rewarded by tenure committees as much as peer reviewed publications or acquiring extramural funding, acquiring teaching skills as a postdoctoral fellow is a waste of time. The majority of postdoctoral trainees still encounter these situations, and many assume that obtaining an advanced science degree and postdoctoral research training will sufficiently demonstrate that they can adequately educate their students. However, hiring institutions know that this is rarely the case.

One model program—the Fellowships in Research and Science Teaching (FIRST) is attempting to improve postdoctoral training in teaching methodology. FIRST is part of an initiative from the Minority Opportunities in Research Division of the National Institute of General Medical Sciences (NIGMS) within the National Institutes of Health (NIH). The initiative provides Institutional Research and Academic Career Development Awards (IRACDA) that combine a traditional mentored postdoctoral research experience at a major research institution with a mentored experience in teaching at Minority Serving Institutions (MSIs). In addition to FIRST, there are eleven other similarly structured programs at the University of Arizona, Tucson; University of California, San Diego; University of California, San Francisco; University of Kansas; Tufts University; University of Minnesota, Duluth; University of North Carolina, Chapel Hill; University of Pennsylvania;

Medical University of South Carolina; Vanderbilt University and Baylor College of Medicine.

FIRST Program

FIRST involves collaboration between Emory University and the minority servicing schools of the Atlanta University Center (AUC): Morehouse School of Medicine, Morehouse College, Spelman College, and Clark Atlanta University. To address issues in science education training for postdoctoral fellows, FIRST implements programs to enrich the next generation of science educators by providing both intensive mentored research and teaching experiences.

The FIRST program trains postdoctoral fellows over three years. While performing research in a laboratory, the fellows are also provided with a teaching development program as follows: (a) a one semester How to Teach course in the 1st year on the philosophy and practice of teaching along with a course-within-a course, (b) teaching mentor selection at one of the AUC schools and preparation over the 2nd year to take a leading role in a course with their mentor, and (c) an opportunity to teach a new or modified course and to conduct science education research in their 3rd year.

Similar to the majority of postdoctoral fellows, FIRST fellows have an intensive laboratory research experience. This research experience continues to be extremely important in being competitive in the academic job market. However, FIRST also provides pedagogical instruction and teaching experiences that should further improve fellow marketability for jobs in academia. Fellows have a mentored teaching experience that takes place at one of the AUC schools. Typically, 15-25% of a fellow's effort is spent on teaching related activities, although the exact schedule for it is flexible. The three-year fellowship training emphasizes modern pedagogy, and a teaching mentor oversees the pedagogic development program of each fellow to ensure that fellows receive the best-suited experience for their future academic career.

During the FIRST program, postdoctoral fellows also have the opportunity to participate in a wide array of workshops and conferences aimed at expanding their knowledge of pedagogical techniques and at helping them succeed in their academic career path. FIRST fellows are also required to attend the annual IRACDA conference where all the fellows from all twelve programs have the opportunity to participate in career development sessions.

Examples of Professional Development Workshops for FIRST Fellows:

1. "Being a Mentor and a Teacher"
2. "How to Publish Educational Research in the Biological Sciences"
3. "Strategies and Tools for Creating and Sustaining an Interactive Classroom"
4. "Considering the Best Practices in Science Education Conference"
5. "Digital Content in Your Class"
6. "How to Use Your Management Style to Effectively Manage the Laboratory and the Classroom"
7. "Effective Leadership"

8. "Case Studies Workshop"
9. "Investigative Cases: A PBL Variant Introduction to Investigative Case Based Learning"
10. "Funding Strategies for Early Career Scientists"

Ninety-one postdoctoral fellows have been part of the FIRST program since its inception. The fellows represent diverse ethnic and educational backgrounds and research areas. The majority of the fellows are minorities, and more than two-thirds are women. Fellows are accepted to the program with from very little to extensive teaching experience. Interestingly, the FIRST program appears to be very appealing to neuroscience trainees since fellows with neuroscience background and research interests make up more than one-third of the present and past fellows.

Most postdoctoral fellows take academic or professional positions that involve responsibilities beyond research—such as teaching, managing laboratories, and writing grants. The FIRST program provides each fellow an experience that much more closely resembles his or their future responsibilities as faculty members than traditional fellowships. Furthermore, the FIRST program allows fellows to have the flexibility to design their own program within broad limits, tailoring their experience to their career goals.

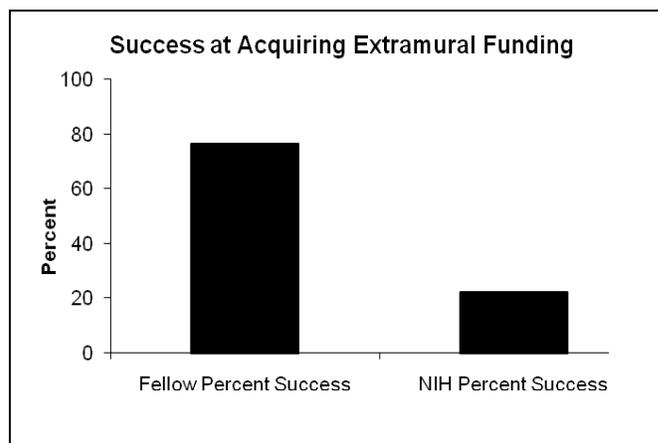


Figure 1. Percentages of graduated fellows successfully acquiring extramural funding after leaving the program compared with typical NIH applicants.

Success of the Program

Interestingly, postdoctoral fellows at Emory University publish at approximately the same rate, irrespective of whether or not they are in the FIRST program. FIRST fellows accomplish this standard while spending approximately 15-25% of their time engaging in teaching-related activities (Holtzclaw et al., 2005).

In addition to publication rate, another way to determine the success of the program is to consider the activities of fellows after they leave the program. One of the key measures of success for academic faculty is their ability to acquire extramural funding. After leaving the program, 60% percent of fellows have applied for extramural funding, and of the 60% that applied, 80% of them have been successful at acquiring funding primarily from

agencies such as the NIH and National Science Foundation (NSF). This far exceeds the typical success rate for applicants of approximately 20% (Figure 1).

Another important measure of the program's success is placement of the fellows in positions after they leave. To date, 75% of the matriculated fellows are now in faculty positions (60% tenure, 15% non-tenure, and 15% of those two are at an MSI), 5% took positions in industry, 8% took positions with government agencies, 6% took positions with non-profit organizations, 3% went into secondary education. In summary, the FIRST prepares program fellows well for success as future researchers and educators.

Educating Undergraduates

Undergraduate education at MSIs is of high importance to the FIRST program. Because of heavy teaching demands, it is sometimes challenging for AUC faculty members to stay abreast of current research. Both lecture and laboratory experiences can become somewhat dated, and as a result students may not be as well prepared for graduate or professional school as they could be (Holtzclaw et al, 2005). Therefore, in the collaboration between Emory University and the AUC, it is vital that the MSIs benefit from the knowledge of contemporary research in fields such as neuroscience that fellows bring when they have their mentored teaching experiences. As a result, FIRST fellows have taught more than 20 different courses at the AUC, many of which are in the field of neuroscience. These courses include Neurobiology, Brain and Behavior, Behavioral Endocrinology, Learning and Memory and Animal Behavior. Because FIRST fellows are introduced to science education research methods, the FIRST program is in a good position to generate important pedagogical data for undergraduate neuroscience course instructors.

In addition to bringing current knowledge of biomedical research in fields such as neuroscience, FIRST fellows also bring to the AUC colleges the current knowledge

regarding how students learn and the most effective instructional techniques, such as active and collaborative learning. Fellows acquire this information partly through their first year How To Teach course but also through ongoing workshops that cover a wide range of teaching methodologies. By sharing this information and demonstrating how new strategies can more effectively educate students, fellows may be able to help to catalyze educational reform in these institutions.

FIRST prepares its fellows to become effective teachers and, therefore, continually evaluates the teaching skills of the fellows during their mentored teaching experiences at the AUC. Fellows distribute teaching evaluations in all of the classes in which they participate and these evaluations are returned to the program and analyzed. According to data from student evaluations collected across several semesters from a wide variety of courses, fellows consistently demonstrate exceptional teaching skills, especially in keeping students engaged, use of technology and overall effectiveness (Figure 2).

To be both interactive and effective during their mentored teaching experiences at MSIs in the Atlanta area, fellows routinely explore innovative teaching methodologies in an attempt to improve classroom learning for minority students. One field in particular with exceptional need for the incorporation of such innovative and interactive teaching methodologies is neuroscience.

Neuroscience is a rapidly evolving field with new departments and courses appearing at colleges and students on evaluations regarding the effectiveness universities regularly, and it has become evident that neuroscience textbooks usually do not contain the most current information on the topic. Therefore, supplementation with innovative and interactive activities that incorporate the most up-to-date information in the field is needed in order to effectively instruct undergraduates in neuroscience (Cleland, 2002). These supplemental activities should be interesting to students, reinforce primary concepts and are appropriate for students with

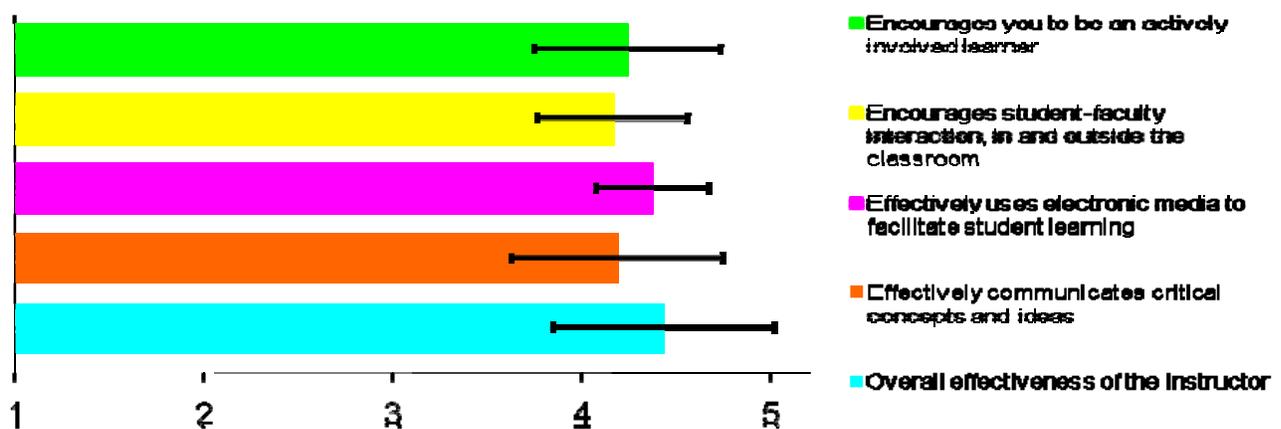


Figure 2. An example of the average responses from students on evaluations regarding the effectiveness and ability of FIRST fellows to engage the students in the classroom based on a 5 point scale with 5=Excellent and 1=Poor.

limited course preparedness and aptitude (Cleland, 2002).

The physiology of action potentials appears to be a significant problem area for undergraduate students (Teyler and Voneida, 1992). Neurophysiology can be particularly intimidating to undergraduates, and it is a critical fundamental concept that must be grasped by students taking neuroscience courses (Stuart, 2008). Techniques such as lecture and repetition are ineffective and time consuming, and excess class time devoted to this topic is at the expense of other important concepts (Teyler and Voneida, 1992). Additional studies also determined that learning in neuroscience is typically aided by interactive environments (Av-Ron et al., 2008). Therefore, we hypothesized that space and time varying material such as the neurophysiology of action potentials would be more effectively communicated by dynamic, interactive exercises. Investigating such exercises should enhance teaching and provide the instructor with more and better instructional tools. We investigated the effects of interactive teaching methods for the topic of action potentials with students taking neuroscience courses.

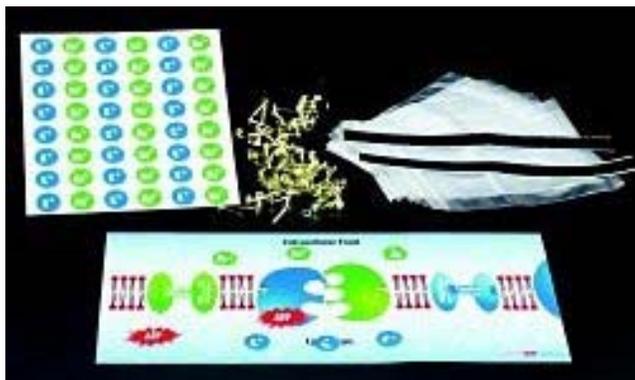


Figure 3. Materials provided in the Action Potential Neuron Manipulatives kit from www.sciencekit.com.

MATERIALS AND METHODS

As mentioned previously, instructing students in the subject of neuroscience can be a daunting task, and one of the most difficult topics for students to comprehend is the generation and propagation of action potentials inside the neuronal axon. Therefore, we tested two interactive teaching methodologies to determine if they would improve learning and retention of this information compared with instruction done with traditional lectures.

During a mentored teaching experience in a Brain and Behavior course in the Psychology Department and a Neurobiology Course in the Biology Department at Spelman College, we investigated the effects of two interactive teaching methodologies compared with traditional lecture for the topic of action potentials. A total of 65 students were involved in these studies. We used two activities and compared them with traditional instruction using lectures. An activity from the Neuroscience Laboratory and Classroom Activities Guide Published by the Society for Neuroscience (SFN) and National Association of Biology Teachers (NABT) was utilized in the Neurobiology Class (Conley and Shepley,

1996). SFN has published a laboratory activity guide on using commonplace materials to assist instructors in achieving maximal student understanding of action potentials. The activity utilizes dried beans of different colors and pie pans as well as some poster board, toothpicks and post-it notes. Different colored beans represent the different ions present inside and outside the cell. During this activity students investigate the movement of ions in and out of the cell during the generation of an action potential by moving the dried beans across their simulated lipid bi-layer on the poster board. After the students move the beans to simulate an action potential, they then use a simulated Sodium/Potassium Pump to return the cell to its resting state. The activity ends with a discussion on how alterations in action potentials contribute to epilepsy (Conley and Shepley, 1996).

An Action Potential Neuron Manipulatives kit from the Science Kits website was used in the Brain and Behavior class (Science Kit & Boreal Laboratories, Tonawanda, NY). This kit (Figure 3) comes with colorful cut-out ions, membrane channels and ATP as well as a placemat with all the components of a neuronal cell membrane. Students follow step-by-step instructions to see how the ions move around during the different phases of the action potential, resting, depolarization, repolarization and hyperpolarization. The activity kit contains a Sodium/Potassium pump and its function is explained and utilized in the activity as well. At the conclusion of this activity, the students answer questions and discuss what they have learned and then apply what they have learned to draw their own action potential graph.

One week after instruction, students were administered a 10 question assessment to determine the amount of information they had understood and retained about the topic. In addition, comments were solicited from the students at the end of each course.

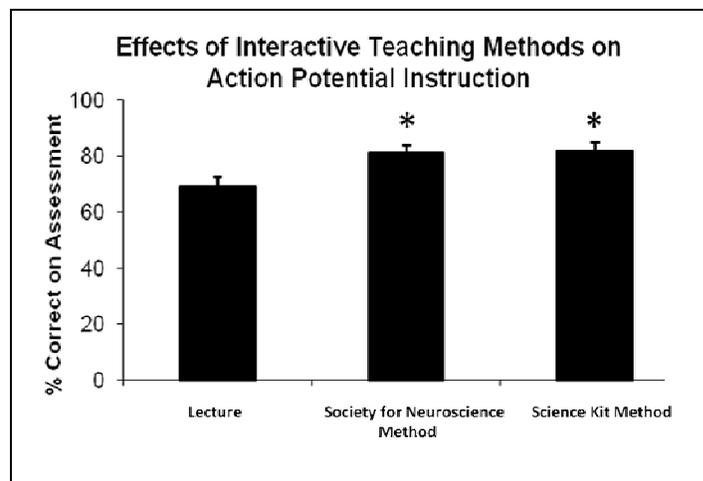


Figure 4. Effect of Interactive Teaching Methods on Knowledge Retention. Percent of correct answers on the action potential assessment one week after instruction. * $p < 0.05$

RESULTS

Students involved in both interactive methods for teaching action potentials had significantly higher correct responses

on the assessment when compared with students who had been exposed to the material through traditional lectures (Figure 4). There was no significant difference in the average number of correct responses between the two interactive methodologies.

Student responses from evaluations indicated that they found the incorporation of interactive teaching methods to be a positive experience that improved their ability to understand and retain class material. In addition, students seemed to prefer this type of teaching when compared with instruction using traditional lectures.

Examples of Comments from the Students on Evaluations:

"I like the in class activities and the homework assignments because they enhance my learning experience."

"I like the in class discussions and activities because they really facilitate the learning process."

"I like that you don't just lecture, and I like working in groups for the in class activities."

"I enjoy this class, specifically the experiments and hands on activities. It breaks up the mundane but inevitable lectures."

"I like that this class is not all lectures and involves exercises and discussion."

"This class has been a great experience for me!"

"Neuroscience has been presented in such a creative way that keeps my attention."

"Our instructor breaks up the lecture with other activities and makes it much more effective."

DISCUSSION

It is evident that traditional postdoctoral training does not adequately prepare fellows for the wide variety of styles of academic positions that PhD trainees attain after completing their academic and postdoctoral training (Adams, 2002). The AACU has indicated that new faculty need to start an academic position prepared to teach effectively using interactive methodology (Adams, 2002). Few postdoctoral programs exist that focus on training postdoctoral fellows in anything other than research (Brommer and Eisen, 2006). Interestingly, postdoctoral fellows that acquire teaching experience along with their research training will most likely have an advantage when searching for academic positions. These fellows should be better prepared to balance teaching, research and service tasks as a new academic faculty member. Therefore, in the highly competitive job market for PhDs seeking positions in academia, it is critical that postdoctoral fellows acquire teaching experience at some point in their training. One such mechanism for acquiring this experience is enrollment in programs such as FIRST.

The FIRST program provides innovative mentored

teaching experiences, specifically at Minority Serving Institutions in Atlanta, and gives fellows a chance to develop innovative teaching methods that increase student knowledge retention. At the same time it provides high quality research training that allows fellows to successfully publish peer reviewed articles and acquire extramural funding. Finally, it gives fellows experience at balancing the research, teaching and service that academic careers demand. Therefore, it is not surprising that postdoctoral fellows that matriculate from the FIRST program are highly successful at acquiring academic positions.

A substantial number of the postdoctoral fellows in the FIRST program are neuroscientists, indicating that this type of training is very appealing to PhDs in this field. It is possible that the popularity of the FIRST training program with neuroscience postdoctoral trainees is due to the inherent difficulty of neuroscience subject matter and their recognition that undergraduate neuroscience courses would benefit a great deal from teaching innovation. The FIRST training program, therefore, provides neuroscience postdoctoral fellows with an arsenal of innovative teaching techniques for their first faculty positions, allowing them better equipped to instruct undergraduate neuroscience students.

Although it is possible that instructor bias influenced student performance on this action potential assessment, data from this study and others continue to indicate that interactive methods for teaching neuroscience, and more specifically action potentials, are beneficial to undergraduates (Teyler and Voneida, 1992; Cleland, 2002; Av-Ron et al., 2008). Employing interactive methodology not only improves retention of the subject matter but also enhances the overall course experience of the students. Since both of the interactive methods were equally effective at increasing knowledge retention, it would appear that the most critical aspect of the instructional technique is its interactivity and not some particular characteristic of that interactive activity. Further research would need to be conducted to determine what particular characteristics of these activities increases knowledge retention and to determine if there are other interactive activities that would be just as effective.

REFERENCES

- Adams KA (2002) What colleges and universities want in new faculty. Washington, DC: Association of American Colleges and Universities.
- Av-Ron E, Byrne JH, Baxter DA (2006) Teaching basic principles of neuroscience with computer simulations. *J Undergrad Neurosci Ed* 4:A40-A52.
- Benyajati S (2007) Finding teaching experiences during your postdoc. *Physiologist* 50:256-257.
- Brommer C, Eisen A (2006) FIRST: A Model for Increasing Quality Minority Participation in the Sciences from the Undergraduate to the Professoriate Level. *J Women and Minorities in Science and Engineering* 12:35-46.
- Cleland, R (2002) Integrating recent advances in neuroscience into undergraduate neuroscience and physiology courses. *Adv Physiol Educ* 26:271-277.
- Conley T, Shepley B (1996) Action potential – epilepsy. In: *Neuroscience laboratory and classroom activities* (Bellamy ML, Frame K, eds) pp191-214. Washington, DC: Society for

Neuroscience.

Holtzclaw JD, Morris LG, Pyatt R, Giver CS, Hoey J, Haynes JK, Gunn RB, Eaton D, Eisen A (2005) FIRST: A model for developing new science faculty. JCST 34:24-29.

Stuart A (2008) *Neurons in Action* in Action: Educational settings for simulations and tutorials using NEURON. Brains Minds Media 3:1-12.

Teyler TJ, Voneida TJ (1992) Use of computer-assisted courseware in teaching neuroscience: The Graphic brain. Am J Physiol 263:S37-S44.

Received June 02, 2009; revised July 16, 2009; accepted July 20, 2009.

This work was supported by a grant from the NIH, NIGMS (MORE Division) GM00680-01A1.

Address correspondence to: Dr. Erin Keen-Rhinehart, Assistant Professor of Biology, Susquehanna University, 514 University Ave., Selinsgrove, PA, 17870, Email: erin@alumni.ufl.edu